# Military Wireless LAN Based on IEEE 802.11b Standard

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## *ABSTRACT*

*This paper describes a civilian WLAN standard adaptation for military purposes. The analysis contains both possible modifications of COTS equipment and construction of brand new solutions, based on existing VLSI integrated circuits. The main goal of each adaptation is utilization of military frequency bands and increase of output power. The paper also contains a description of own designed WLAN board.*

## 1.0 INTRODUCTION

Modern military communications systems (MCS) use many solutions dedicated for their special utilization. In the past, in MCS mainly specialized devices were used. They were not interoperable with commercial solutions and even with similar systems used by other nations. Now MCS use more widely commercial products (COTS – Commercial of the Shelf). Unfortunately, military requirements for such systems and products are more restrictive than for commercial purposes.

It results mainly from MSC requirements, where hierarchical command process is realized in the distributed, ad-hoc or mesh mobile network environment. These systems have to be susceptible to continuous reconfiguration and decentralization, and should be survivable, manageable and redundant in disadvantage grids.

Available COTS equipment for establishing WLAN use 2400 – 2500 MHz civilian ISB frequency band. It doesn't match military requirements, where two frequency band can be considered: band I (225-380 MHz) for long range networks (up to several kilometers) and band IV (4,4-5 GHz) for short range, up to several hundreds meters [5].

Change of frequency range causes a need for adaptation of physical layer of the link: signal structure, spreading bandwidth, data rate and output power. An analysis and optimization of diverse reception, used types of antennas and practical verification of useful ranges and data rates in variable propagation conditions is also necessary.

Projects related to adaptation of civilian WLANs were initiated and are coordinated by NC3A. Currently several NATO countries are involved in different projects related to this topic. These projects are in different stages of realization and concern both adaptation to band I and band IV [6,7].

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## 2.0 MILITARY REQUIREMENTS FOR WLAN BASED COMMUNICATION SYSTEMS

Taking into account the MCS tasks, many requirements for the COTS products have been defined [1]. They are as follows:

- Mobility. The communication infrastructure is characterized by dynamic (often and rapidly) changing topology. Each network elements can be deployed in different places in MCS structure but they have to be linked in hierarchical command system.
- Throughput. Data rate ranging from 2.4 kbps to 2.048 Mbps, and even up to 50 Mbps in the Command Posts (CP).
- Security. The role of the security is to protect the data being held by Communications and Information System. It refers to the ability of protection against unauthorized access to the stored, processed and exchanged information. It is applied to information as well as to voice protection and data flow control.
- Interoperability. The ability of systems to provide services and accept services from other systems. Appropriate interoperability level is required and specified by NATO.
- Manageability. The ability of the information and communication systems to be properly managed.
- Survivability. Communications systems have to be built with such redundancy that allows services provision in intentionally disaster conditions.
- Quality of service. This requirement concerns all mentioned above requirements and moreover, the communication services availability. The services should be permanently available for subscribers.

Formal criteria (such as maturity, availability and stability) for adoption of the COTS products for military purposes are defined in [2]. Commercial success of WLANs shows that such technology is also interesting for military networks. Besides, technical architecture for NATO systems specified in [2] allows the WLAN technology to be used in military applications.

Recently, additional requirements are defined for the WLANs. They are as follows:

- military frequency adjustment (225÷400 MHz and 5.25÷5.85 GHz),
- communication range improvement,
- power control efficiency,
- minimal power consumption,
- handover and mobility management.

Currently existing COTS WLANs are not suitable for such requirements. These limitations can be overcome by, change of frequency band, increase of output power and modification of the physical layer and MAC operation. It requires some adaptation of existing hardware solutions and software controlled communication protocol.

## 3.0 POSSIBLE ADAPTATION APROACHES

Adaptation of WLAN can be performed in two different ways:

- Using existing COTS WLAN products and modifications: without changing existing products – by applying external frequency shifters and power amplifiers or modifying products - e.g. changing frequency of clocks, exchanging filters etc.
- Using existing COTS VLSI circuits dedicated for WLAN applications and implementing them in own construction.

Advantages of the first solution are low cost of products and short time of implementation. Costs of COTS WLAN are usually about 100 ... 300 USD, but they radio parameters were adjusted for 2.4 GHz ISM band. Using signals with the same parameters in another frequency band can cause change of overall parameters of the system. Despite proper operation of particular units, the system can work inefficiently.

Additional units, like frequency shifters for transmission and reception must be designed. The problem can also arise with diverse reception using two antennas. In this case modification of original WLAN card structure may be necessary to control switching the antennas. This problem can be neglected for short range communications, although an overall performance of the system can be degraded. For long range links selection of proper antenna is an essential problem and has a major influence on system parameters.

Second approach is much more expensive and time consuming. It is necessary to design quite new equipment and elaborate new software. The main advantage of such solution is a possibility of multi-layer optimization of transmission, according to current propagation conditions. Moreover, it is possible to design a flexible multi band tool, which will be able to control its parameters automatically. These properties convinced us to design a laboratory model of a WLAN board using COTS VLSI integrated circuits.

## 4.0 PROPOSED SOLUTION

Research project launched in Institute of Telecommunications MUT is a project of a WLAN board using COTS VLSI integrated circuits, based on PCI interface.

The VLSI circuits chosen for this implementation are INTERSIL chips, because of their flexibility and wide range of possible adaptations. According to their frequency ranges, spreading methods and communication architecture families PRISM, PRISM II, PRISM III and PRISM III+ are available. Most advanced and flexible is PRISM II chipset [8, 9]. The specific feature of this chipset is separation of the signal processing functions between several chips. It enables accommodation of the final architecture to the current needs. Main chips realize the following functions:

- MAC processor,
- baseband processor with signal shaping units,
- modulator/demodulator with frequency synthesis,
- frequency shifter.

Because MAC processor includes communications procedures dedicated for WLAN 802.11 working in ISM 2.4 GHz band and civilian data security functions (WEP engine), it is useless for our application. We decided to replace it with general purpose 16-bit micro-controller.

The MILWLAN model board structure is as follows:

- chipset Intersil PRISM2 – HFA 3863, HFA 3783,
- FPGA based glue logic,
- optional ciphering FPGA chip,
- 16 bit H8 controller (MAC processor),
- external 10 W amplifier.

The board is a „plug &play" board with its own drivers.

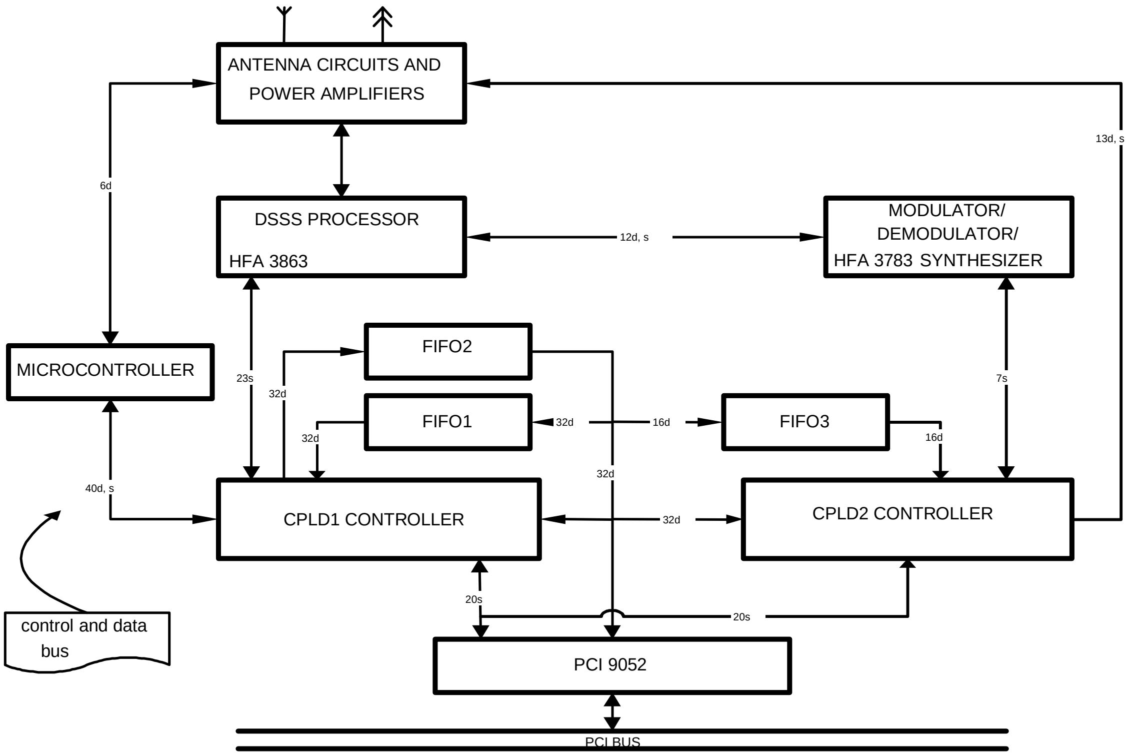


**Figure 1: Block diagram of designed MILWLAN board**

**Figure 2: Designed MILWLAN board**

# 5.0 SIMULATION MODEL

Although Intersil specifications of PRISM chips indicate, that chips should work properly in variable conditions, the MILWLAN application requires their use in a specific configuration. Especially, instead of fixed clock signal, a frequency synthesizer is used to obtain lower data rates and spreading frequencies. To verify if the chips are working properly, a simulation model in MATLAB was created. The main assumption was to simulate PRISM logic blocks. The model doesn't contain coding/decoding block and packet formatting procedures, hence these parameters aren't necessary for MILWLAN board verification. The model can be extended to perform further simulation related both to coding procedures, packet length selection and connection establishing protocols.

**Table 1. Parameters of implemented simulation model of 802.11 physical layer**

| | |
|---|---|
| Modulation | DBPSK |
| Spread spectrum | DS SS |
| Spreading code | 11 bit Barker code |
| Data rate [ Mb/s] | 1; 0,5 ; 0,25 |
| Spreading frequency [MHz] (bandwidth) | 11; 5,5 ; 2,75 |
| Transmission channel | AWGN, AWGN+FIR (6-paths with Rice fading) |
| Intermediate frequency [MHz] | 70 |
| Fiters delays estimation | Yes |
| Transmission quality merit | BER |
| Error correction | No |
| Synchronization | Perfect |

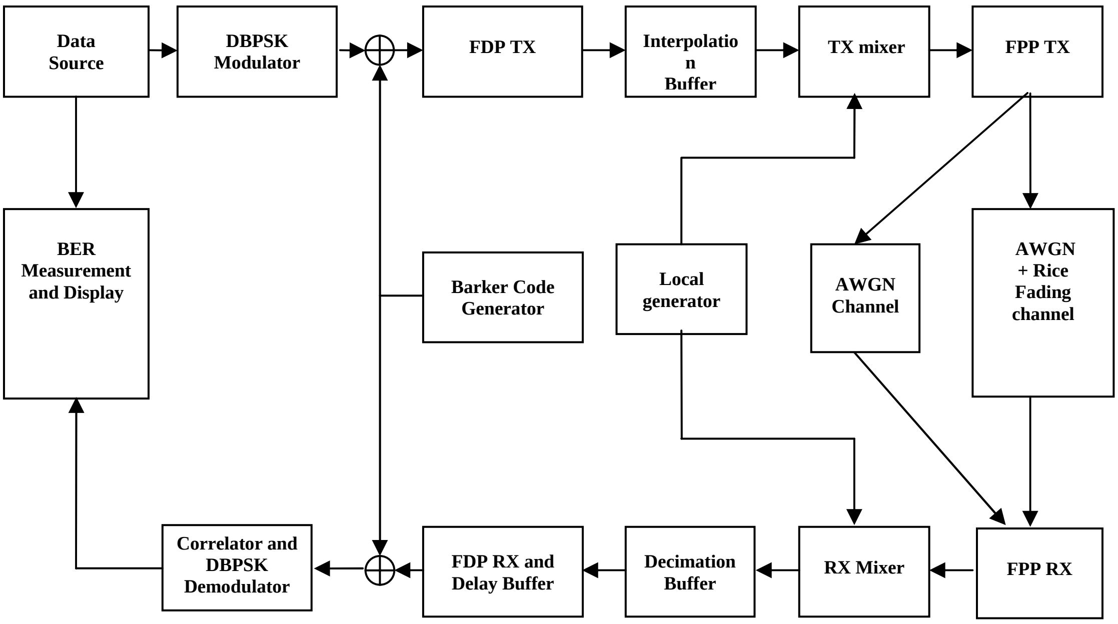


**Figure 3: Block diagram of simulation model**

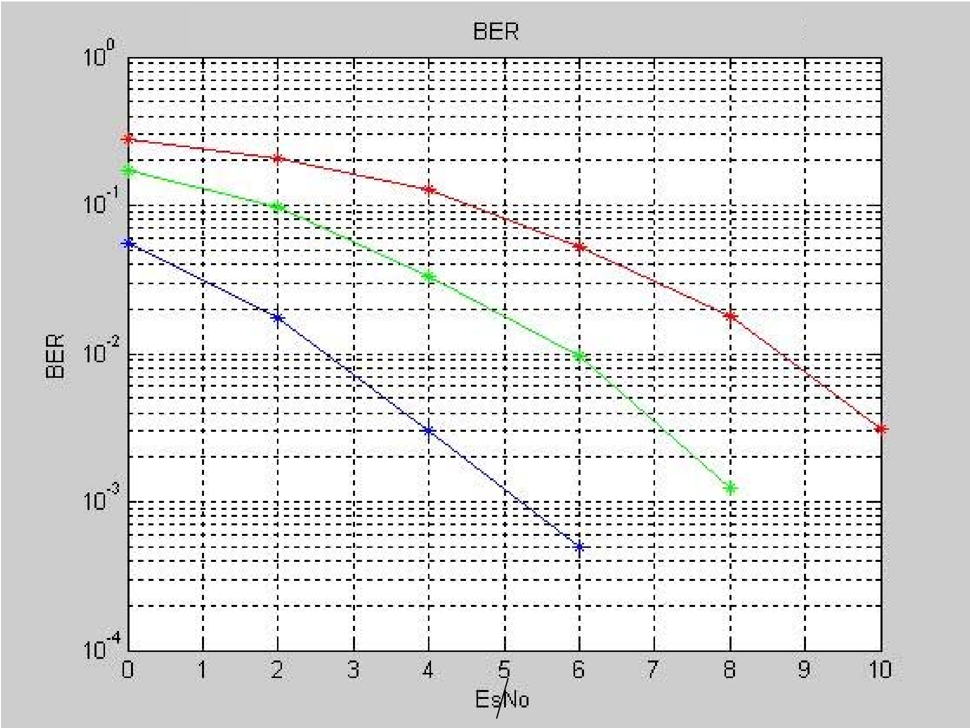


**Figure 4: BER for AWGN channel, spreading frequency 11MHz versus Es/$N_0$ for different data rates: red – 1MB/s, green – 0,5 Mb/s, blue- 0,25 Mb/s**

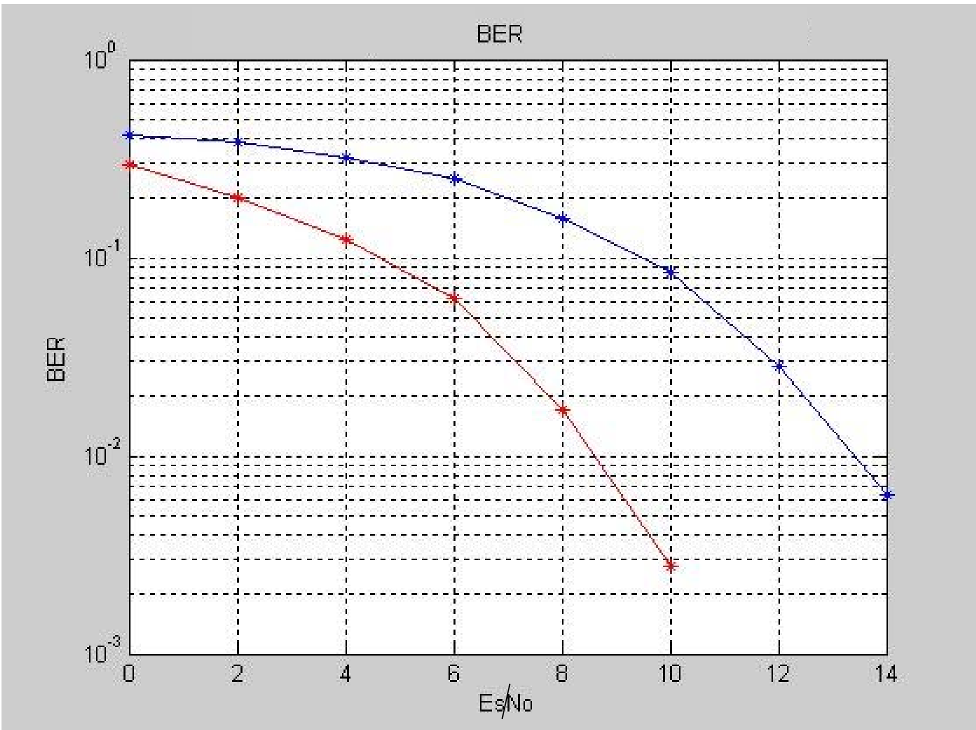


**Figure 5: BER for AWGN channel and 6 path Rician fading, spreading frequency 11MHz and data rate – 1MB/s versus Es/$N_0$: red – AWGN channel, blue- AWGN channel plus Rician fading**

## 6.0 CONCLUSIONS

The civilian WLANs are very promising and prospective communications systems, but they have several drawbacks from military point of view. Increases of communication range and data security are the major. To fight with these problems a special MILWLAN boards were designed, using programmable and flexible COTS chips. Currently we are working on the low level software, and for verification of the chips operation a simulation model of the board is used. The model operation was verified by comparison with BER characteristics, published by Intersil. Differences for 1Mb/s data rate and AWGN channel were smaller than 2dB.The model is a flexible tool and can be extended according to current needs. It can be also used for investigation of influence of coding parameters, packets length, header structure etc. Instead of simulated radio channels, parameters of real propagation conditions can be also included. It allows verification and optimization of equalization procedures efficiency, power adaptation and antenna selection algorithms etc.

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# Military Wireless LAN Based on IEEE 802.11b Standard

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# COTS WLAN poperties

**ADVANTAGES**

- High capacity (1, 2, 5.5 and 11 Mbit/s)
- Flexibility
- Transparent for commercial software
- Low cost of equipment

**DISADVANTAGES**

- The ISM frequency range (2.4 GHz) is not a military band
- The output power of the COTS cards is too small (100 mW)
- The ISM signal is strongly attenuated in forest and hilly terrain
- The range between computers usually doesn’t exceed hundred meters
- Data security (WEP) is insufficient

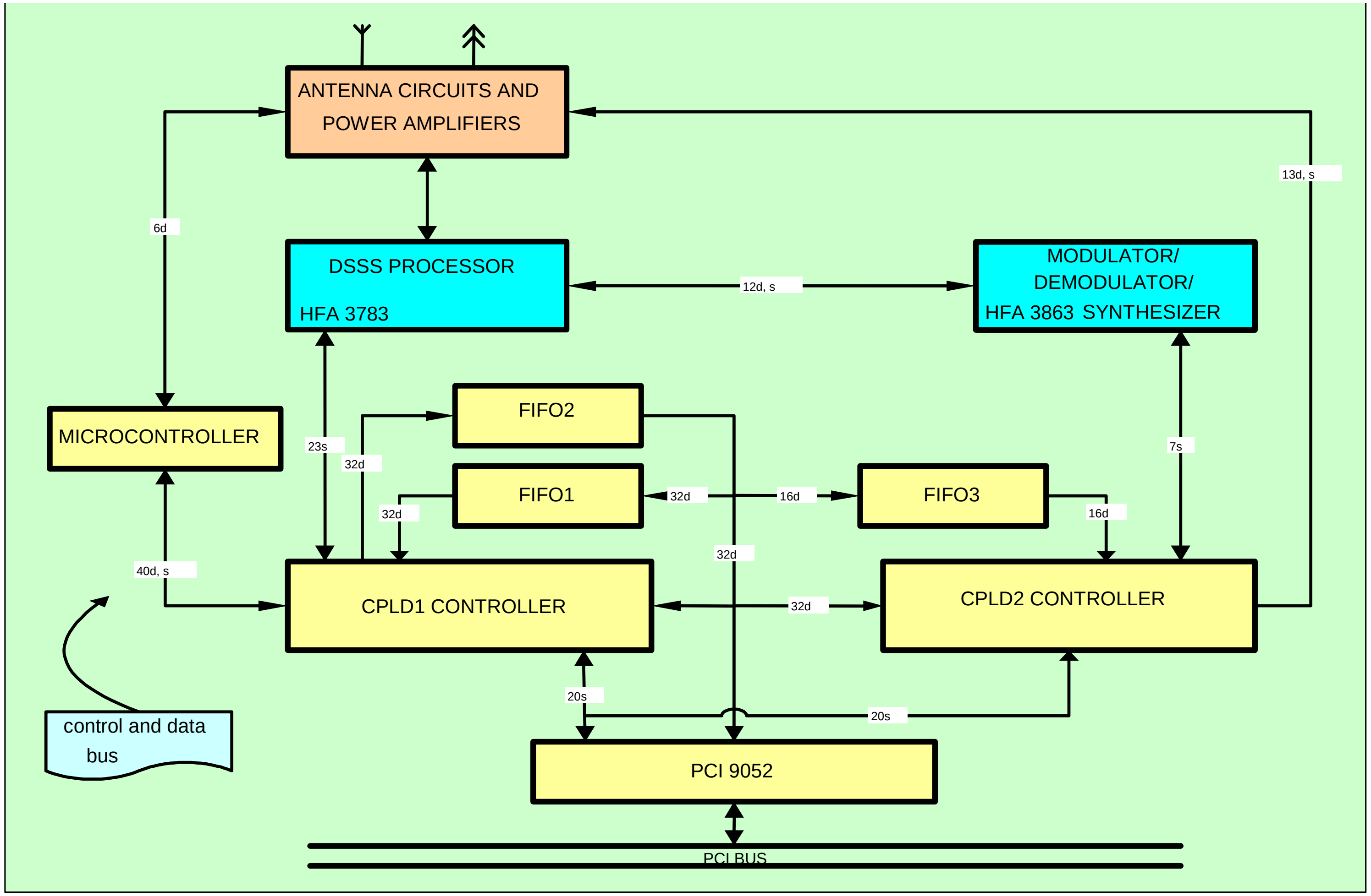
# Proposed solution

- For short distances 4.4-5.0 GHz band should be used
- To increase the usable range, the frequency has to be reduced (225 – 400 MHz band)
- Transmitted power should be increased (controlled)
- For long distance connections data rate must be lower
- Signal bandwidth must be lower for lower frequency bands
- Encryption module is required

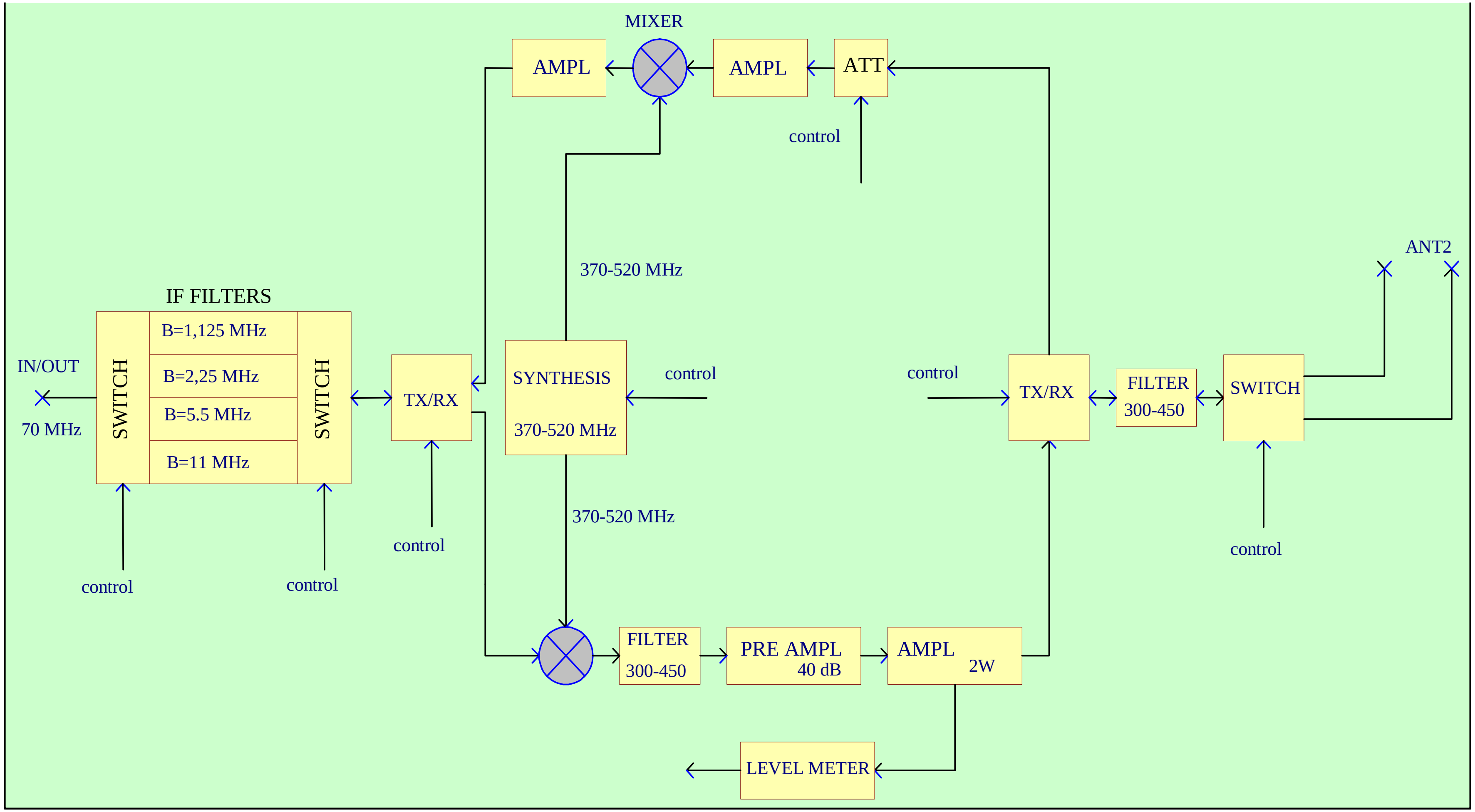
**IMPLEMENTATION OF THE MWLAN SYSTEM**

- The choice should be made based on minimizing development cost and depend on the radio technology available for use
- PRISM II chipset made by Intersil is often used in 802.11b-cards – MAC is implemented in separate chip
- External amplifier is necessary
- PCI or USB interface is required

# Block diagram of the MWLAN board

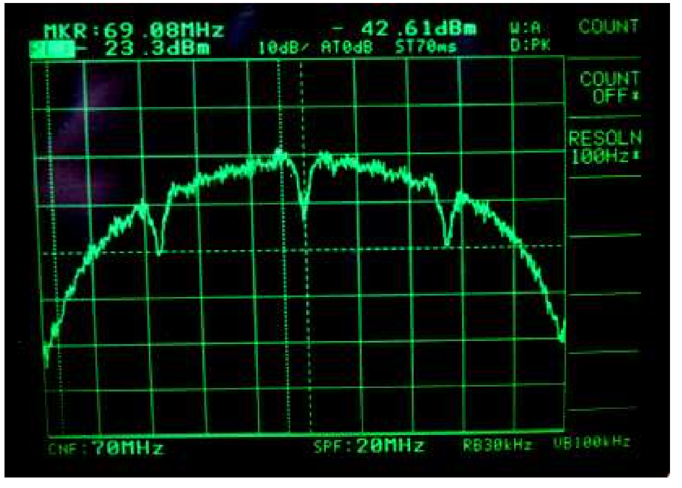


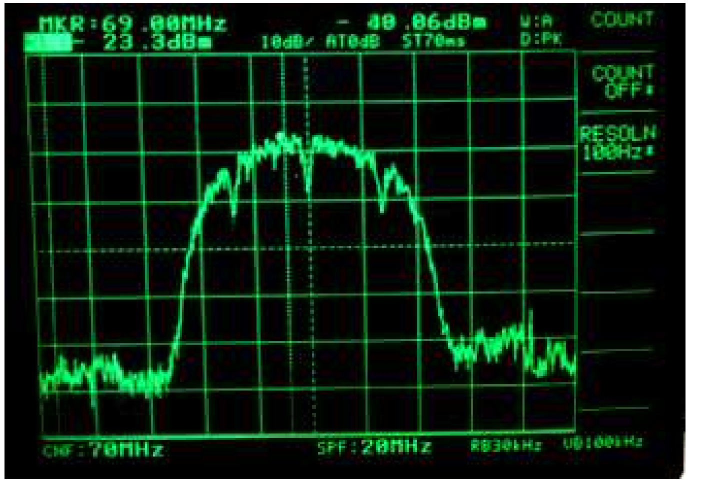
# Amplifiers and antenna circuits

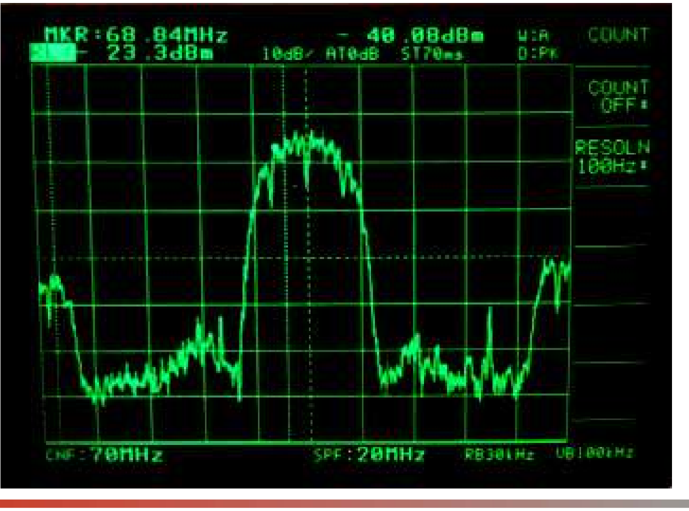


# MWLAN PCI board

# IF spectra

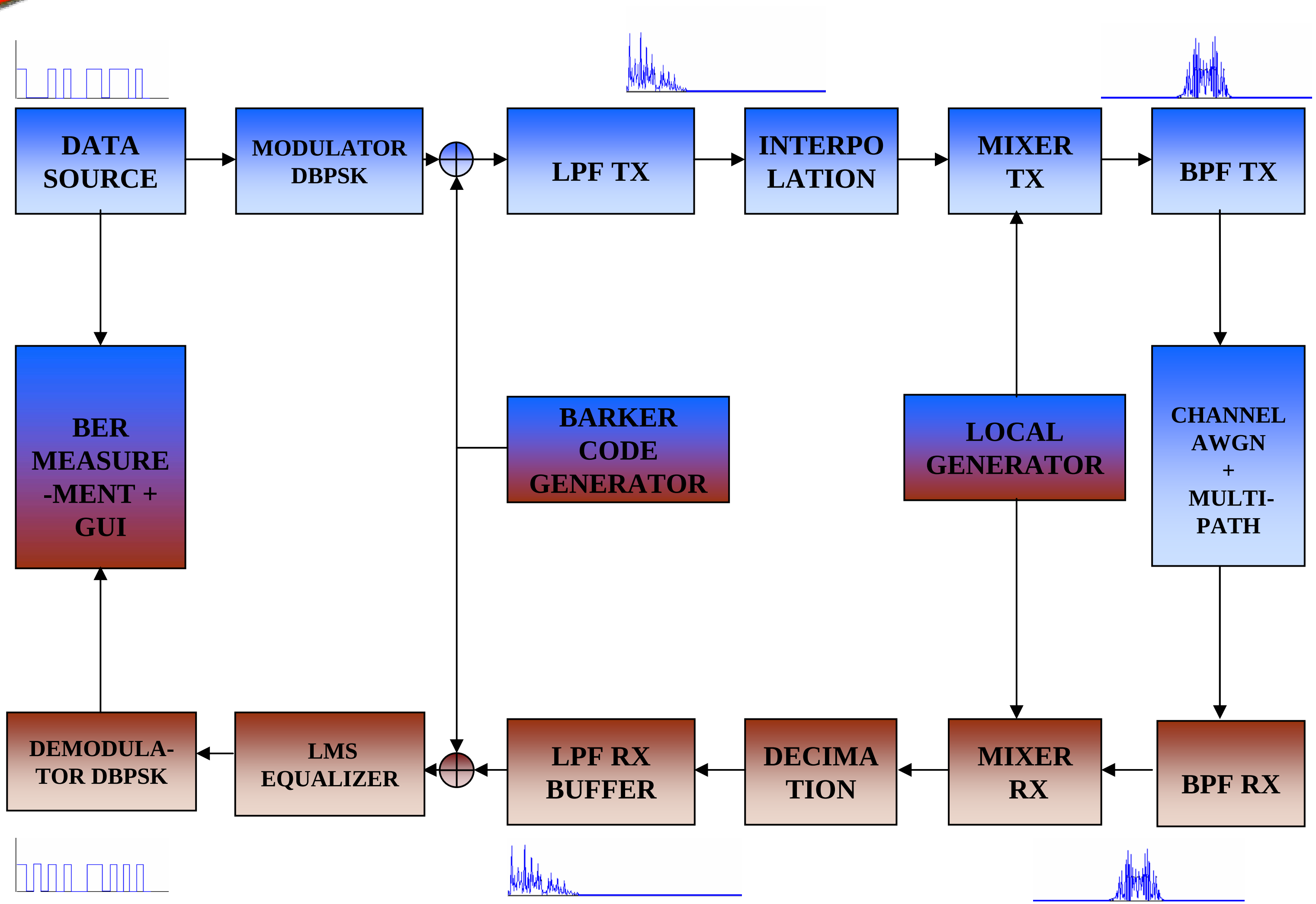

MKR:69.08MHz - 42.61dBm
23.3dBm 10dB/ AT0dB ST70ms
W:A D:PK
COUNT
COUNT OFF
RESOLN 100Hz
CNF:70MHz
SPF:20MHz
RB30kHz VB100kHz


MKR:69.00MHz - 40.06dBm
23.3dBm 10dB/ AT0dB ST70ms
W:A D:PK
COUNT
COUNT OFF
RESOLN 100Hz
CNF:70MHz
SPF:20MHz
RB30kHz VB100kHz

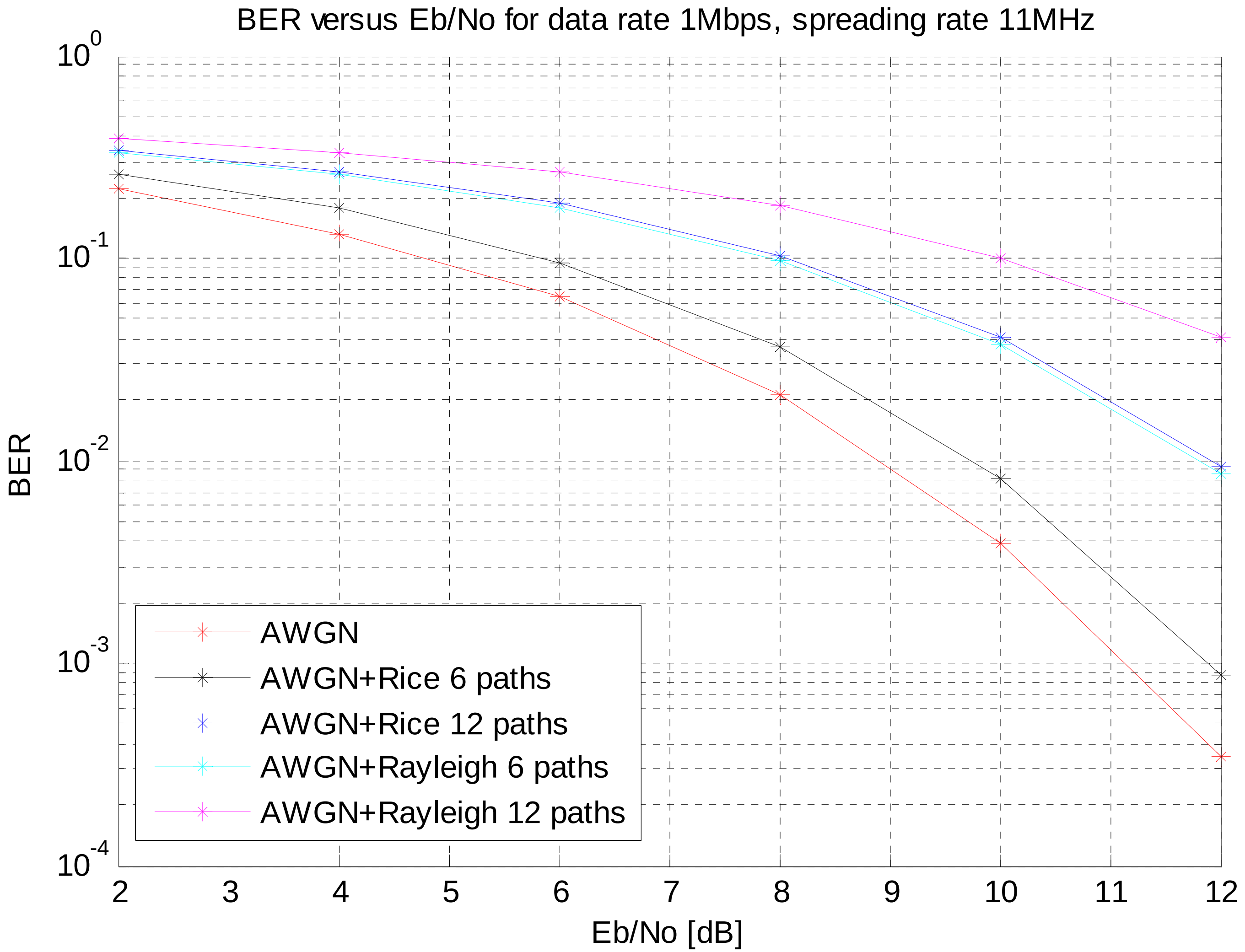

MKR:68.84MHz - 40.08dBm
23.3dBm 10dB/ AT0dB ST70ms
W:A D:PK
COUNT
COUNT OFF
RESOLN 100Hz
CNF:70MHz
SPF:20MHz
RB30kHz VB100kHz


MKR:69.12MHz - 42.01dBm
23.3dBm 10dB/ AT0dB ST70ms
W:A D:PK
COUNT
COUNT OFF
RESOLN 100Hz
CNF:70MHz
SPF:20MHz
RB30kHz VB100kHz

# Block diagram of simulation model



# Simulation results



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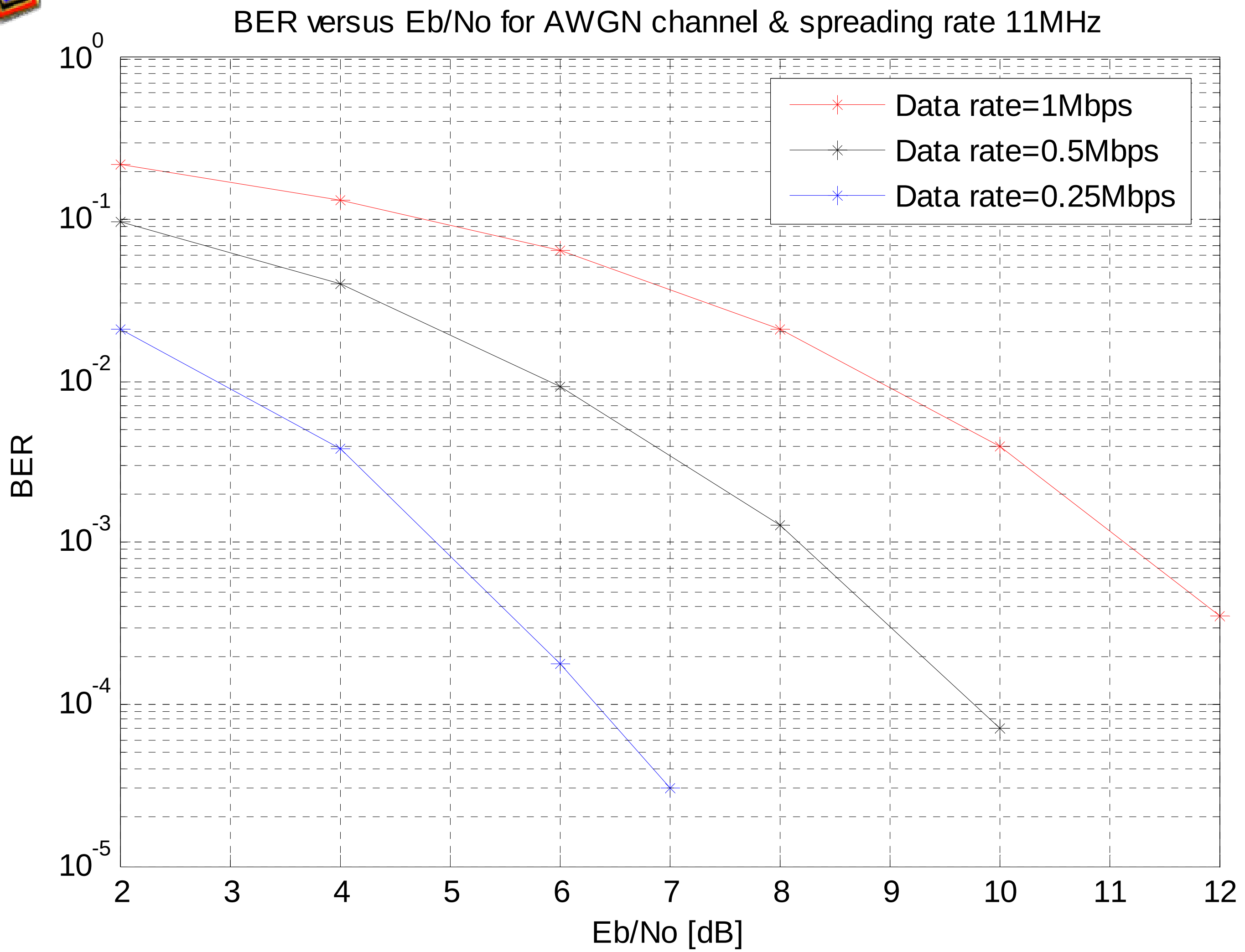

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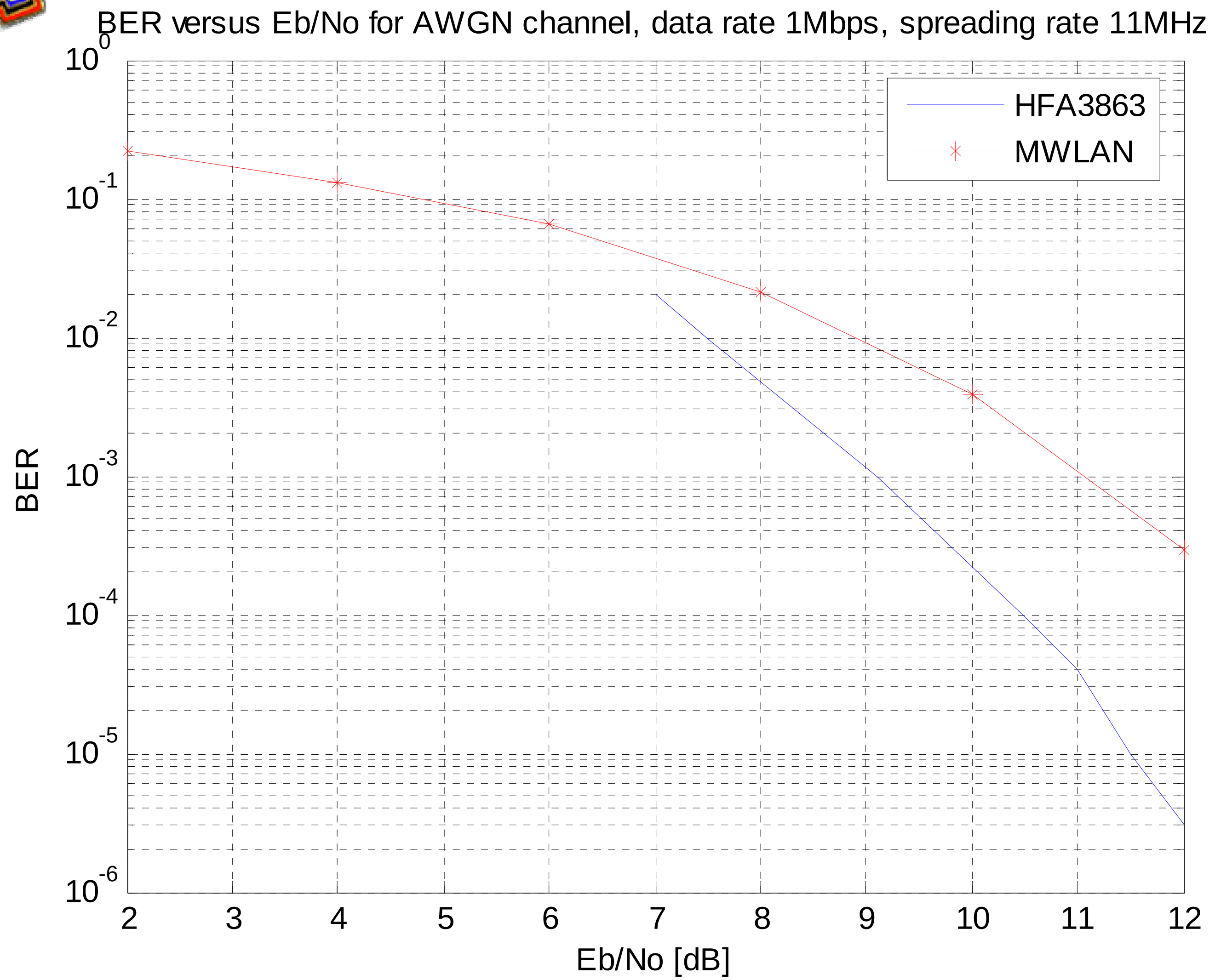

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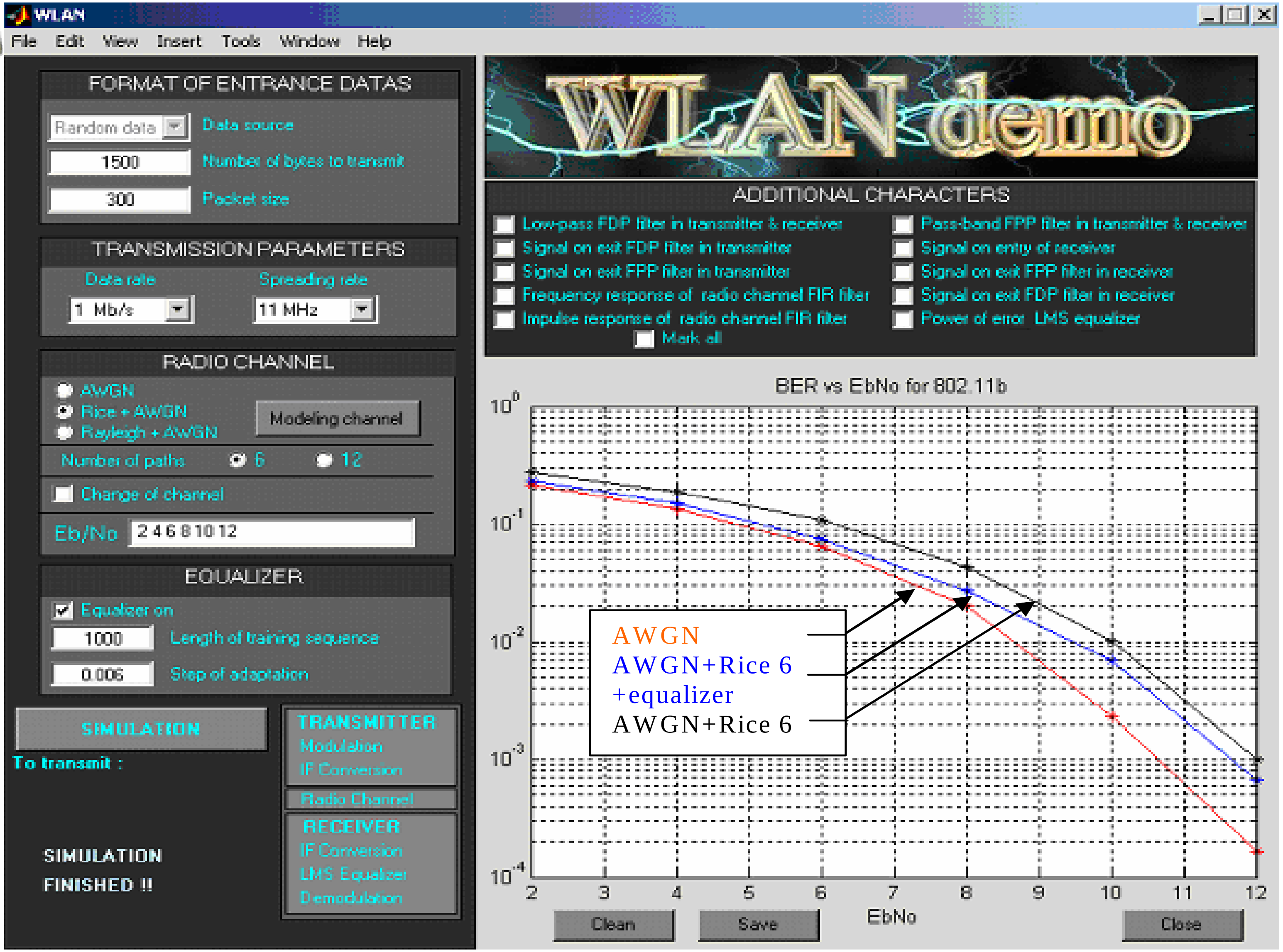

# Conclusions

- WLAN is a promising and flexible communication technology
- COTS solutions can't be adapted easily for MCS requirements
- Elaborated simulation model enables verification of MWLAN board configuration and operation
- The model can be extended to optimize higher layer protocols

**WORK TO COMPLETE THE MWLAN PROJECT**

- RF module completion (AGC control)
- Peer-to-peer communications practical tests
- Peer-to-peer communications protocol optimization
- TCP/IP implementation
- Encryption implementation
- Network mode, using protocols adapted from 802.11b
- Network mode optimization